

AD-A260 020

(2)

1

CONTRACT NO. N00014-86-K-0766

"Polymers By Non-Redox Processes:  
Synthesis, Physical Studies  
and Application"

DTIC  
ELECTE  
JAN 26 1993  
S C D

FINAL REPORT

SEPTEMBER 16, 1986 - OCTOBER 31, 1989

PRINCIPAL INVESTIGATOR:

ALAN G. MACDIARMID

Department of Chemistry  
University of Pennsylvania  
Philadelphia, PA 19104-6323

Tel: (215) 898-8307

Fax: (215) 898-8378

10  
AP  
93-00735

DISTRIBUTION STATEMENT A

Approved for public release  
Distribution Unlimited

93 1 12 031

The research conducted under this contract is continuing in Grant No. N00014-90-J-1559. It is a continually funded effort.

The work conducted under Contract No. N00014-86-K-0766 and continued under Grant No. N00014-90-J-1559 will be summarized in the list of technical reports, patents and personnel included in the Final Report for Grant No. N00014-90-J-1559.

Listed below are the publications supported in whole or in part by the URI Contract No. N00014-86-K-0766 from September 16, 1986 to October 31, 1989.

*Alan G. MacDiarmid*

Alan G. MacDiarmid  
December 4, 1992

Accession For	<i>✓</i>
NTIS	GRANT <input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unpublished	<input type="checkbox"/>
Justification	<input type="checkbox"/>

*Ref AD-A205553*

*Information*

*AD-A205553 Codes*

*100-100-100-100*

*100-100-100-100*

*A-1*

**66 PUBLICATIONS SUPPORTED**  
**IN WHOLE OR IN PART**  
**BY URI CONTRACT FROM**  
**9/16/86 THROUGH 10/31/89**

CONTRACT NO.: N00014-86-K-0766

**"POLYMERS BY NON-REDOX PROCESSES:  
SYNTHESIS, PHYSICAL STUDIES  
AND APPLICATION"**

September 16, 1986 to October 31, 1989

**PRINCIPAL**

**INVESTIGATOR:** Alan G. MacDiarmid  
Department of Chemistry  
University of Pennsylvania  
Philadelphia, PA 19104-6323  
Tel: (215) 898-8307  
Fax: (215) 898-8378

Research Groups

1. University of Pennsylvania  
Department of Chemistry (A.G. MacDiarmid)
2. The Ohio State University  
Department of Physics (A.J. Epstein)
3. Lockheed Advanced Aeronautics Corporation  
Aeronautics Systems Group Research (T.S. Kuan)
4. Drexel University  
Department of Chemistry (Y. Wei)
5. University of Rhode Island  
Department of Chemistry (S.C. Yang)
6. Montclair State College  
Department of Chemistry (B.D. Humphrey)
7. University of Pennsylvania  
Department of Materials Science and Engineering (G.C. Farrington)
- 8a. Massachusetts Institute of Technology  
Department of Chemistry (G.E. Wnek)
- 8b. Rensselaer Polytechnic Institute  
Department of Chemistry (G.E. Wnek)

PAPERS PUBLISHED = 66

A. Published Papers — (1987) = 5

1. "Insulator-to-Metal Transition in Polyaniline," Solid State Commun., 63, 97 (1987), J.M. Ginder, A.F. Richter, A.G. MacDiarmid and A.J. Epstein.
2. "Transport Studies of Protonated Emeraldine Polymer: A Granular Polymeric Metal System," Physical Review B, 36, 3475 (1987), F. Zuo, M. Angelopoulos, A.G. MacDiarmid, and A.J. Epstein.
3. "Are Semiconducting Polymers Polymeric Semiconductors?: Polyaniline as an Example of 'Conducting Polymers,'" Conducting Polymers, L. Alcácer, Ed., (Reidel Publications, Dordrecht, Holland), p. 121 (1987), A.J. Epstein, J.M. Ginder, A.F. Richter and A.G. MacDiarmid.
4. "Microwave Response of Confined Soliton Pairs (Bipolarons) in (N-Methyl-phenazinium)<sub>x</sub> (Phenazine)<sub>1-x</sub>(Tetracyanoquinodimethanide)," Phy. Rev. Lett., 59, 1760 (1987), H.H.S. Javadi, J.S. Miller and A.J. Epstein.
5. "Influence of Oxidation State, pH, and Counterion on the Conductivity of Polyaniline," J. Phys. Chem., 91 (22), 5813 (1987), W.W. Focke, G.E. Wnek and Y. Wei.

B. Published Papers — (1988) = 24

1. "Polyaniline: A New Concept in Conducting Polymers," International Symposium on Development of Conducting Organic Polymers and Ultra-Thin Films and Their use in Electronics, (Iva-Rapport, Stockholm, Sweden), 352, 6 (1988), A.G. MacDiarmid.
2. "Solid-State <sup>13</sup>C NMR Characterization of Polyanilines," J. Am. Chem. Soc., 110, 7647 (1988), S. Kaplan, E.M. Conwell, A.F. Richter and A.G. MacDiarmid.
3. "Polyaniline: Solutions, Films and Oxidation State," Mol. Cryst. Liq. Cryst., 160, 151 (1988), M. Angelopoulos, G.E. Asturias, S.P. Ermer, A. Ray, E.M. Scherr, A.G. MacDiarmid, M. Akhtar, Z. Kiss and A.J. Epstein.
4. "Protonation of Emeraldine: Formation of a Granular Polaronic Polymeric Metal," Mol. Cryst. Liq. Cryst., 160, 165 (1988), A.J. Epstein and A.G. MacDiarmid.
5. "Electrochemistry of Ring Substituted Polyanilines: Effect of Substituents on Electronic Properties," Mol. Cryst. Liq. Cryst., 160, 221 (1988), A. Ray, J.-C. Chiang, A.G. MacDiarmid, Y. Wei, W.W. Focke, G.E. Wnek and A.J. Epstein.
6. "Pseudo-Protocatic Acid Doping of Polyaniline," Mol. Cryst. Liq. Cryst., 160, 223 (1988), M. Angelopoulos, S.P. Ermer, S.K. Manohar, A.G. MacDiarmid and A.J. Epstein.

7. "Frequency Dependent Conductivity of Emeraldine: Absence of Protonic Conductivity," Mol. Cryst. Liq. Cryst., 160, 225 (1988), H.H.S. Javadi, F. Zuo, M. Angelopoulos, A.G. MacDiarmid and A.J. Epstein.
8. "A Covalent Bond to Bromine in HBr Treated Polyaniline From X-Ray Diffraction," Synth. Met., 22, 191 (1988), B.K. Annis, A.H. Narten, A.G. MacDiarmid and A.F. Richter.
9. "Segmented Polyacetylene,  $(CHDy)_x$ : Electrochemical N-Doping Studies," Synth. Met., 24, 283 (1988), M.X. Wan, G.A. Arbuckle, A.G. MacDiarmid and A.J. Epstein.
10. "Conduction Mechanism of Polyaniline: Effect of Moisture," Synth. Met., 26, 1 (1988), H.H.S. Javadi, M. Angelopoulos, A.G. MacDiarmid and A.J. Epstein.
11. "Microwave Conductivity and Dielectric Constant of  $(TMTTF)_2X$ , X=SCN,  $ReO_4$ ,  $SbF_6$ ," Synth. Met., 27, 23 (1988), R. Laversanne, H.H.S. Javadi and A.J. Epstein.
12. "Photoexcitation of Polarons and Molecular Excitons in Emeraldine Base," Phys. Rev. Lett., 60, 2789 (1988), M.G. Roe, J.M. Ginder, P.E. Wigen, A.J. Epstein, M. Angelopoulos, and A.G. MacDiarmid.
13. "Photoexcitations in  $La_2CuO_4$ : 2eV Energy Gap and Long Lived Defect States," Phys. Rev. B., 37, 7506 (1988), J.M. Ginder, M.G. Roe, R.P. McCall, Y. Song, J.R. Gaines, E. Ehrenfreund and A.J. Epstein.
14. "Microwave Conductivity and Dielectric Constant of  $(TMTTF)_2X$ , X = SCN,  $ReO_4$ ,  $SbF_6$ ," Phys. Rev. B., 37, 4280 (1988), H.H.S. Javadi, R. Laversanne and A.J. Epstein.
15. "Photoinduced Absorption in the  $La_{2-x}Sr_xCuO_4-\delta$  System: 2 eV Bandgap and Long-Lived Defect States," Mat. Res. Soc. Symp. Proc., 99, 857 (1988), A.J. Epstein, M.G. Roe, J.M. Ginder, F. Zuo, R.P. McCall, Y. Song, X.-D. Chen, J.P. Golben, J.R. Gaines, P.E. Wigen and E. Ehrenfreund.
16. "Nonlinear Optical Properties of Polyaniline," Mat. Res. Soc. Symp. Proc., 109, 313 (1988), A.J. Epstein, J.M. Ginder, M.G. Roe, T.L. Gustafson, M. Angelopoulos and A.G. MacDiarmid.
17. "Electrochemical and Stability Studies of a New Form of Polyacetylene,  $N-(CH)_x$ ," Extended Abstracts, The Electrochemical Society, 174th Meeting, Chicago, IL, October 9-14, 88-2, (1988), R. Huq, G.C. Farrington, J. Foreman, K. Wu and N. Theophilou.
18. "Solid Polymer Electrolytes: Zn(II) Mobility in Poly(ethylene oxide)," Extended Abstracts, The Electrochemical Society, 174th Meeting, Chicago, IL, October 9-14, 88-2, (1988), H. Yang and G.C. Farrington.
19. "DMA and DSC/DETA of Poly(ethylene oxide)-Based Electrolytes," Proceed. of The 17th NATAS Conference, Lake Buena Vista, FL, October 9-12, p. 335, (1988), G.K. Jones, A.R. McGhie, R. Huq and G.C. Farrington.

20. "Reactions of N-type (Reduced) Polyacetylene with Alkyl Halides," Macromolecules, 21, 266 (1988), D. H. Whitney and G. E. Wnek.
21. "A Comment on Random Versus Non-Random Defect Placement in Polyacetylene," Makromol. Chem. Rapid. Commun., 9, 535 (1988), S. Clough, S. Tripathy, X. Sun, B. Orchard and G.E. Wnek.
22. "Electrochemistry of Polyaniline: Consideration of a Dimer Model," Symp. Proc. Electroactive Polymers, P. Prasad and D. Ulrich, Eds., (Plenum Press, New York), p. 315 (1988), W.W. Focke and G.E. Wnek.
23. "Conduction Mechanisms in Polyaniline (Emeraldine Salt)," J. Electroanal. Chem., 256, 343 (1988), W.W. Focke and G.E. Wnek.
24. "Anomalous Magnetic, Photoinduced and Structural Phenomena in High T<sub>c</sub> Materials," in First Two Years of High Temperature Superconductivity, (Gordon Breach Publishers, NY), p. 113 (1988).

### C. Published Papers — (1989) = 37

1. "The Polyanilines: Processing, Molecular Weight, Oxidation State and Derivatives," Polymer Preprints, 30, 147 (1989), A.G. MacDiarmid, G.E. Asturias, D.L. Kershner, S.K. Manohar, A. Ray, E.M. Scherr, Y. Sun, X. Tang and A.J. Epstein.
2. "Highly-Conducting Polyacetylene," Synth. Met., 28, 35 (1989), N. Theophilou, D.B. Swanson, A.G. MacDiarmid, A. Chakraborty, H.H.S. Javadi, R.P. McCall, F. Zuo, S.P. Treat, and A.J. Epstein.
3. "Polyanilines: Doping, Structure, and Derivatives," Synth. Met., 29, 141 (1989), A. Ray, G.E. Asturias, D.L. Kershner, A.F. Richter, A.G. MacDiarmid and A.J. Epstein.
4. "Polyaniline: Protonation/Deprotonation of Amine and Imine Sites," Synth. Met., 29, 151 (1989), A. Ray, A.F. Richter, A.G. MacDiarmid and A.J. Epstein.
5. "The Oxidation State of 'Emeraldine' Base," Synth. Met., 29, 157 (1989), G.E. Asturias, R.P. McCall, A.G. MacDiarmid and A.J. Epstein.
6. "A Solid State NMR Investigation of the Structure and Dynamics of Polyanilines," Synth. Met., 29, 235 (1989), S. Kaplan, E.M. Conwell, A.F. Richter and A.G. MacDiarmid.
7. "<sup>15</sup>N NMR of Polyaniline," Synth. Met., 29, 243 (1989), A.F. Richter, A. Ray, K.V. Ramanathan, S.K. Manohar, S.J. Opella, G.T. Furst, A.G. MacDiarmid and A.J. Epstein.

8. "Polyaniline: Kinetics of Electrochemical Doping Studied by Time Resolved Absorption Spectroscopy," Synth. Met., 29, 251 (1989), D. Zhang, J.H. Hwang and S.C. Yang.
9. "Morphological Modification of Polyaniline Using Polyelectrolyte Template Molecules," Synth. Met., 29, 271 (1989), J.H. Hwang and S.C. Yang.
10. "Poly-(2-Methylaniline): The Effect of Chemical Modification on the Insulator/Conductor Transitions of Polyaniline," Synth. Met., 29, 337 (1989), R.L. Clark and S.C. Yang.
11. "N-Substituted Derivatives of Polyaniline," Synth. Met., 29, 349 (1989), S.K. Manohar, A.G. MacDiarmid, K. Cromack, J.M. Ginder and A.J. Epstein.
12. "Electronic Phenomena in Polyaniline," Synth. Met., 29, 395 (1989), J.M. Ginder, A.J. Epstein and A.G. MacDiarmid.
13. "Experimentally Determined pH-Potential Phase Diagram for Polyaniline: Clues for Optically Distinguishable Sub-Phase in the Conductor Form," Synth. Met., 29, 401 (1989), S.C. Yang, R.J. Cushman and D. Zhang.
14. "Charge Transport in the 'Emeraldine' Form of Polyaniline," Synth. Met., 29, 409 (1989), H.H.S. Javadi, F. Zuo, K. Cromack, M. Angelopoulos, A.G. MacDiarmid and A.J. Epstein.
15. "Photoexcitations in 'Emeraldine' Base," Synth. Met., 29, 425 (1989), M.G. Roe, J.M. Ginder, R.P. McCall, K.R. Cromack, A.J. Epstein, T.L. Gustafson, M. Angelopoulos and A.G. MacDiarmid.
16. "IR Absorption, Photoinduced IR Absorption and Photoconductivity of Polyaniline," Synth. Met., 29, 433 (1989), R.P. McCall, M.G. Roe, J.M. Ginder, T. Kusumoto, A.J. Epstein, G.E. Asturias, E.M. Scherr and A.G. MacDiarmid.
17. "ESR of Protonated 'Emeraldine': Insulator to Metal Transition," Synth. Met., 29, 439 (1989), H.H.S. Javadi, R. Laversanne, A.J. Epstein, R.K. Kohli, E.M. Scherr and A.G. MacDiarmid.
18. "Solution Studies of the Emeraldine Oxidation State of Polyaniline," Synth. Met., 29, 445 (1989), F. Zuo, R.P. McCall, J.M. Ginder, M.G. Roe, J.M. Leng, A.J. Epstein, G.E. Asturias, S.P. Ermer, A. Ray and A.G. MacDiarmid.
19. "Vapor Deposited Polyaniline," Synth. Met., 29, 451 (1989), K. Uvdal, M. Logdlund, P. Dannetun, L. Bertilsson, S. Stafstrom, W.R. Salaneck, A.G. MacDiarmid, A. Ray, E.M. Scherr, T. Hjertberg and A.J. Epstein.
20. "Photoinduced Absorption Studies of La-Cu-O and Y-Ba-Cu-O Systems," Synth. Met., 29, 563 (1989), J.M. Ginder, M.G. Roe, R.P. McCall, A.J. Epstein, E. Ehrenfreund, Y. Song, J.R. Gaines and S.I. Shah.

21. "AC Conductivity of Emeraldine Polymer," Phys. Rev. B, 39, 3570 (1989), F. Zuo, M. Angelopoulos, A.G. MacDiarmid and A.J. Epstein.
22. "Microwave Transport in the Emeraldine Form of Polyaniline," Phys. Rev. B, 39, 3579 (1989), H.H.S. Javadi, F. Zuo, M. Angelopoulos, A.G. MacDiarmid and A.J. Epstein.
23. "Massive Polarons In Large-Gap Polymers," Phys. Rev. B, 39, 10174 (1989), R.P. McCall, J.M. Ginder, M.G. Roe, G.E. Asturias, E.M. Scherr, A.G. MacDiarmid and A.J. Epstein.
24. "Multiple Lattice Phases and Polaron Lattice/Spinless Defect Competition in Polyaniline," Phys. Rev. B Rapid Comm., 39, 12958 (1989), M.E. Jozefowicz, R. Laversanne, H.H.S. Javadi, A.J. Epstein, J.P. Pouget, X. Tang and A.G. MacDiarmid.
25. "Reduced Interchain Spin Diffusion in Trans-Polyacetylene Due to  $sp^3$  Orbital Defects," Phys. Rev. B, 40, 3176 (1989), Y.Cao, J.R. Gaines, A.J. Epstein, G.A. Arbuckle and A.G. MacDiarmid.
26. "Picosecond Photoinduced Exciton Bleaching in Emeraldine Base: Crossover in Decay Mechanisms," Phys. Rev. B, 40, 4187 (1989), M.G. Roe, J.M. Ginder, T.L. Gustafson, M. Angelopoulos, A.G. MacDiarmid and A.J. Epstein.
27. "The Application of Electrochemistry to the Measurement of Selected Intrinsic Physical Properties of Polyacetylene," J. Chem. Phys., 90(9), 5102 (1989). R.B. Kaner, S.J. Porter, D.P. Nairns and A.G. MacDiarmid.
28. "Synthesis and Electrochemistry of Alkyl Ring Substituted Polyaniline," J. Phys. Chem., 93, 495 (1989), Y. Wei, W.W. Focke, G.E. Wnek, A. Ray and A.G. MacDiarmid.
29. "Studies of the Hydration of Transition Metal Cations Dissolved in Poly(ethylene oxide) by UV/Visible Spectroscopy," J. Electrochem. Soc., 136, 1260 (1989), R. Huq, M.A. Saltzberg and G.C. Farrington.
30. "The Synthesis and Characterization of Polyaniline/Polysaccharide Conducting Composites," J. Electrochem. Soc., 136, 3711 (1989), H. Weiss, O. Pfefferkorn, G. Kotora and B.D. Humphrey.
31. "The Effect of N-Phenyl-P-Phenylenediamine On the Electro-Polymerization of Aniline," J. Electr. Chem. Soc., 89(1), 810 (1989), S.K. Preto Clement and R.E. Cameron.
32. "Glass Transition of Chemically Synthesized Polyaniline," Polym. Mat. Sc. & Eng., 61, 916 (1989), Y. Wei, G.-W. Jang, K. F. Hsueh, E. M. Scherr, A. G. MacDiarmid and A. J. Epstein.
33. "Ring Rotational Defects in Polyaniline," Solid State Commun., 72, 987 (1989), J.M. Ginder, A.J. Epstein and A.G. MacDiarmid.

34. "Absorption and Photoinduced Absorption Studies of  $\text{La}_2\text{CuO}_4$  and  $y\text{Ba}_2\text{Cu}_3\text{O}_{6+x}$ : Role of Defect States," in The Electronic Structure of High Tc Superconductors, A. Bianconi and A. Marcelli, Eds., (Pergmon Press), p. 87 (1989), A.J. Epstein, J.M. Ginder, J.M. Leng, R.P. McCall, M.G. Roe, J.J. Ye, W.E. Farneth, E.M. McCarron and S.I. Shah.
35. "Development and Properties of Polyaniline-Polyimide Blends," in SAMPE, 1139 (1989), R.E. Cameron, S.K. Preto and A.L. Landis.
36. "Charge Carrier Chemistry in Electroactive Polymers," in Functional Polymers, Bergbreiter and Martin, Eds., (Plenum Press, New York), p. 107 (1989), G.E. Wnek.
37. "PEO-based Polymer Electrolytes Containing Divalent Cations," Polymer Electrolyte Rev. B, J.R. MacCollins and C.A. Vincent, Eds., (Elsevier Publishers, Switzerland), p. 255 (1989), G.C. Farrington and R.G. Linford.